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Site Selection of Small Modular Reactor (SMR) plants and final disposal sites of related spent nuclear fuel

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Background

- Use of SMRs for district heating → location possibly closer to population/urban environment than in case of normal NPPs.
- Effect of the size of the SMR unit: e.g. 30 MW (small district heating reactor) versus 300 MW (Loviisa NPP 500 MW). Passive safety features.
- Emergency zones in case of an accident:
    - *5 km for normal NPPs in Finland (STUK Y-2/2018)*
    - *Guidelines given on the effect of the plant size in IAEA SSG SG-G-2.1 (table 8):*
        - *Precautionary action zone PAZ: none (<100 MW (th)), 0,5-3 km (>100-1000 MW (th))*
        - *Urgent protective action planning zone UPZ: 0,5-5 km (<100 MW (th)), 5-30 km (100-1000 MW (th)).*
    - *Atmospheric dispersion discussed in PIEMOS project, case specific evaluations needed.*
    - ***Outside scope of this work!***
- In addition to plant siting, activities linked to waste management (at least handling and interim storages, but possibly also disposal in final repositories, e.g. for VLLW) should to be taken into account in siting.
- City planning, location with respect to infrastructure, availability of cooling water, population distribution and societal acceptability.
- Espoo has reserved a site for a SMR in Ämmässuo (in city planning), HS 13.10.2022, old landfill area with little amount of people living in the area.
- **SMRSiMa siting work focuses on site requirements from geological point of view!**

Introduction

- Existing legislation, guidelines and regulations from IAEA, STUK
  - *YVL A2 (STUK)*
    - *General notifications of geological, hydrological, seismological, meteorological etc. factors that influence safety of a nuclear installation*
  - *IAEA Safety Requirement documents*
    - *Requirements for geological investigations regarding nuclear facilities*
- These documents concern nuclear facilities in general, no SMR specific guidelines exist.
- Current Nuclear Energy Act reformation to include SMR technologies

Geological Criteria for SMR plant siting

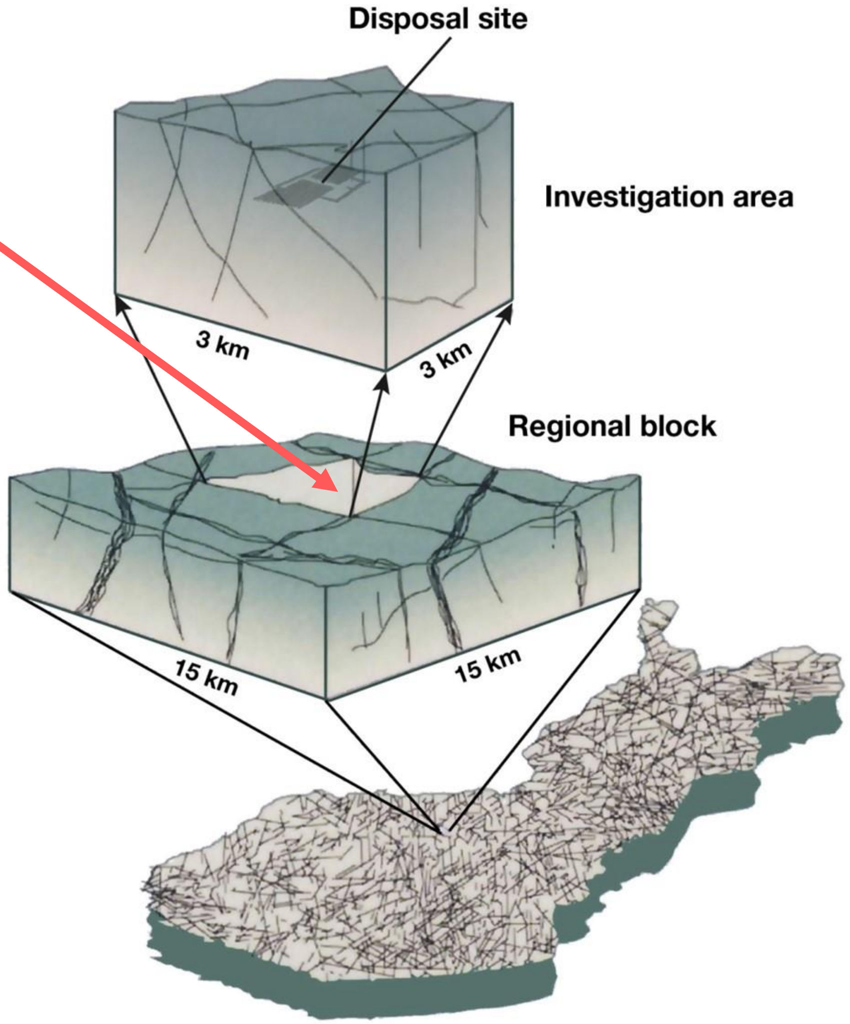
- Geological criteria are derived from IAEA safety guides for conventional NPPs which include other criteria such as human, environmental, radiological etc. factors
- Geological criteria are still applicable for SMR plant siting as they are defined by e.g., IAEA safety standards for *nuclear facilities* (SSR-1, SSG-35)
  - *Geological features and geotechnical hazards: Geological features of subsurface and surface materials with geotechnical characteristics, geotechnical hazards*
  - *Seismic hazards: evaluation of fault capability, ground motion hazards* (also human induced), *volcanic hazards*
  - *Flooding hazards evaluation*
- A singular SMR plant site specific surface area could be much smaller than conventional NPP site (small SMR plant , e.g. <50 MW)
  - *Size or scale factor of the SMR plant is beneficial*
  - *Reduces risk of exposure to larger scale capable faults*
- Large SMR plant (several hundred MW), same rules apply as for normal NPPs. Effect of passive safety features should be discussed.
- Ranking and exlusion of areas and sites based on defined geological criteria
- Databases for geological, seismic, geophysical, geochemical, rock mechanical, hydrological etc. data as defined by IAEA
- Urban area infrastructure, underground/surface construction, cooling and related water management

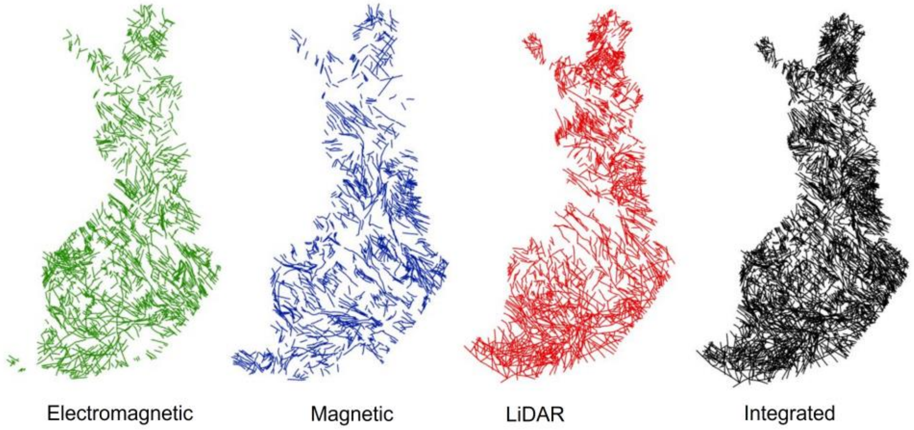
Options for SMR spent nuclear fuel repository with geological criteria

- **Same rules apply as for any SNF/LILW/VLLW repository in Finland**
- Currently centralized option more favorable than e.g., decentralized facilities within the SMR plant site
- Decentralized option means that geology probably changes
    - *Similar requirements will have to be met in different geological environments (i.e., lithology, faulting, fracturing)*
- Centralized option offers far more enhanced and cost-effective geological data from a single repository
- A ranking system based on geological criteria
    - *Each category will receive point totals for different geological qualities*
    - ***Bedrock block size, bedrock topography conditions, homogeneity, faulting, fracturing, outcrop exposure rate***
- SMR reactor fuel waste stream effects on SMR repository geological criteria
    - *Spent fuel characteristics need to be taken into account in planning of the repository (e.g. layout, distances between deposition holes and tunnels and EBS (e.g. burnups).*
    - *Further research required*

Geological investigations:

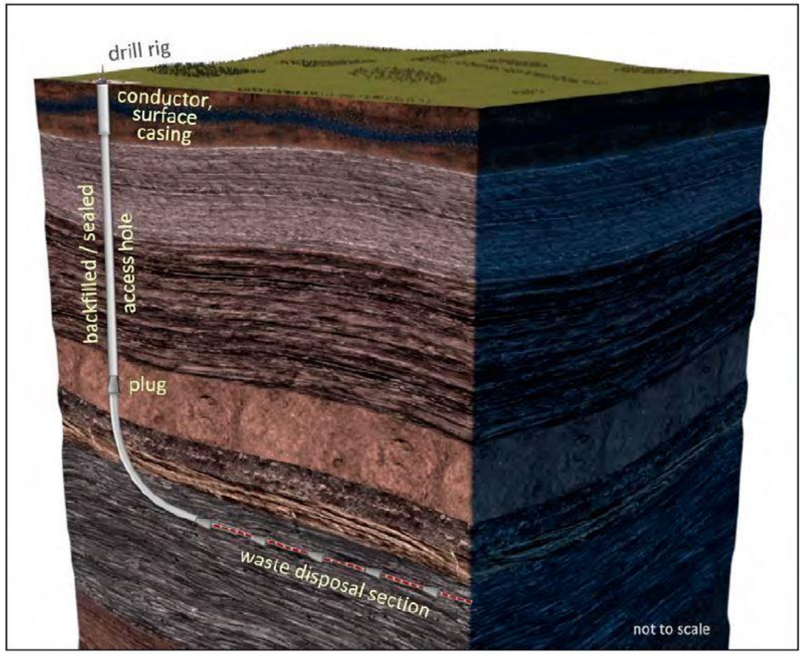
- **Starting with lineament interpretation at different scales and data types that delineate an intact bedrock block.**
- Site specific scale e.g., < 1: 50 000
- Electromagnetic, magnetic, LiDAR, integrated
- Principles for conventional SNF repositories
- Applicable for SMR sites with scale difference and site surface area in mind
- Rating and exclusion of several areas with level of geological investigation detail increasing towards site selection
- Applies to both SMR plant site selection and SMR SNF repository site selection





Deep Borehole Deposition

- Basic idea of a very thick natural barrier
  - *Technical barriers play a lesser role in DBD*
  - *Distance from biosphere*
    - *Orders of magnitude longer distance than conventional repository depths*
  - *Selection of geological media via drilling*
- Horizontal vs. vertical drillhole
- Multiple boreholes vs. single boreholes
  - *Changes in level and scale of geological investigations*



Modified from Muller et al., 2019

- Environmental effects will be different in all phases compared to a mined repository concept
  - *Differences in surface footprint*
- Centralized vs. decentralized options
  - *Placement within or near developed SMR SNF sites?*
- **Limitations in deep data aquisition, site selection and investigability, lesser amount of hard data than conventional repositories**
- Development of appropriate drilling technology
- Every country, state and continent (EU, USA, Asia) has their own starting point based on geological conditions

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Thank you for listening

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